

# Resolving Form Generations through Analogue and Digital Human Simulations

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## ABSTRACT:

Architectural investigation of forms through parametric equations and transcendental computational research is evolving the practice, development, and implementation of complex forms. Architectural concepts require adaptability to a variety of complementary human factor considerations including constructability, ecologically sensitive building systems, and human comfort considerations, that would benefit from the inclusion of human factor simulations of person with disabilities. The position of this writing supports the application of dynamic human factors modelling to transcendental computation data-based form generation for the development of advanced architectural forms, of which there are three potential long-term target influences. The first of these is the potential for multi-faceted transcendental computation data based forms in the development of ideas relating to the application of accessible solutions in architecture. The second is the collection of parameters relevant to code-based constraints in the development of human factors simulators, which contain data relative to variations in human physiology and cognition based on models of impairment and disability. The third is the review of concepts for developing human factor simulators to inform design choices respondent to issues of accessibility in the development of spatial relationships, and the performance of tasks in the generation of the two.

Currently a digital model can be evaluated for conflicts and use variables of human factor simulators programmed to engage the representation of environmental conditions data.<sup>1</sup> By developing architectural concepts from software which are capable of studying whole-body, musculoskeletal human simulations of persons with varying physical, cognitive, and psychological capabilities, complex computational data-based forms can evolve to benefit people in environmental conditions that are currently underserved. The testing of patterns of use for mechanical equipment have successfully been developed based on anthropometric analysis and equal ergonomic simulation.<sup>2</sup> The intent of this research is to develop the premise that a complex computational based architectural form can be generated from parameters of physiological and ergonomic ranges through simulation of use patterns based on information available in the building code and influenced by the definition of environmental use. The use of rapid prototyping tools and CAD/CAM technologies for development and evaluation of the resultant generated forms would be for the synthesis of virtual concepts with allotted physical tolerances to validate compliance, while simultaneously evaluating fabricating processes for conditional ease of assembly and performance.

CONFERENCE THEME: Embracing Humanity

KEYWORDS: Egress, Physiology, Behavior, Simulation, Design

## INTRODUCTION

In finding ways to incorporate the capabilities of assistive technologies into better design solutions for those whose physical condition clearly presents greater difficulties, informs the functions of independence in everyday life. The human body is in a constant state of flux; evolving to adhere to the environment and devolving due to age. These changes introduce new design dilemmas and constraints that the design of dynamic transitional forms can respond to. This research into the application of human functional data to computational based form generation has three potential long-term influences. The first of these is the potential of collecting computational data in the development of simulations relating to accessible solutions in architecture. The second is the creation of variables relevant to code-based constraints in the development of human factor simulators; those which contain data relative to variations in human physiology, and those which are cognition based, on models of impairment and disability. Finally, is the review of concepts on developing human factors simulators to inform design choices in the development of spatial relationships and the performance of tasks in the generation of the two.

The connection of the variables of postural and motion-based spatial arrangements as gathered from simulations within a design and fabrication tool in the generation of the form, are useful in evaluating variations in the tolerances for both that address the fluctuation in code based design guidelines (Table 1). Critical compliance variations in model codes would actively adjust the model to generate forms that are responsive to “live” changes. These changes would be tracked to catalogue the effects on each stage of the process, with the intent of decreasing the “tolerance for error”<sup>3</sup> while increasing the active capability for changes throughout the project phases.

These tolerances, produced from examination of analogue prototype testing, will determine areas where a range field is more suitable than an exact dimension. This will allow the form to have a less arbitrary response to conditions, and will allow for the evaluation of stronger solutions by querying the selection of a series of systemic equations with an active global influence. In areas of importance, where greater focus on motion and discomfort simulations are needed to evaluate distortions, the query will employ more variables, and in less codified variable situations, the program will rely on stronger external aesthetic forces.

Designs using these variables as a guide would reflect with greater ease the wide variation of human needs. Investigations through qualitative measures, expressive of an understanding of user variations, would match the query with the theoretical potential of complex virtual solutions. An example of the proposed development would be solutions for egress from vertical spatial transitions and the analysis of use in the generation of a wall and stair assembly as a transitional form and the consideration of its expression along all three axes. The need to provide options in exiting vertical structures to the ground plane, that allows types of egress based on varying physical ability, would be evaluated as an active connection between variables of the distortion and parameters of safe transition between levels. Studying these differences in the progression of form, when the wall or stair distort singularly along different axes versus when connected to other environmental conditions including human functional data, will aid in understanding the degrees of latitude which can be incorporated into the model constraints to ensure compliance without restricting the generation of a form.

### 1.1. THE PURSUIT OF THE FORM FOR FUNCTION

The potential for anthropometrically based design solutions to provide choice at multiple design scales is based on several factors. These factors include a design, which is consciously aware of the target user(s) ability to wilfully communicate, move through, or engage the environment. This should be accomplished without encountering measures that prevent the fulfilment of personal independence or collective participation due to a lack of variety and adaptability by the environment.<sup>4</sup>

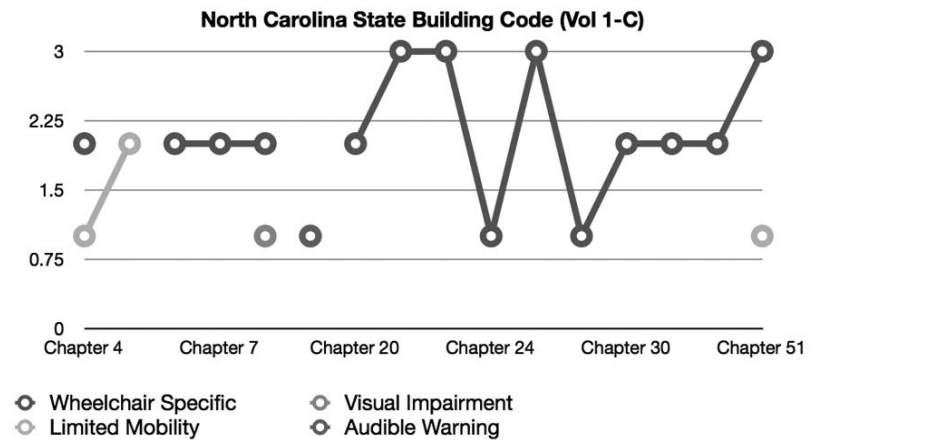


Table 1: References to specific disabilities in examples of state and national codes.

This healthier environment does directly relate to greater light, cleaner water, fewer emissions, and a more natural setting by which we can live our lives, but equally relates to ability and the tolerances for the variation in our physical stature and ability.<sup>5</sup> These directly relate to our psychological strength, and ability to relate to the environment.<sup>6</sup>

Environmental deviance is appreciated for its variability where the intended spatial reactions are different from what is proposed. To a certain degree, this requires an acceptance of social deviance from the intended order or patterns of expected use (Table 2, Figure 2). In the case of passage as a means of egress from a building, the designer assumes that the intended users will be coherent and calm enough to navigate out of the building and those exiting with impairments, such as visual impairments, will be patient and calm enough to read Braille signage directing their way. It is therefore plausible that there is a need for resolution of these issues based not upon the capabilities of the mean user type, but rather from the extremes of the spectrum to address a more inclusionary set of solutions. The realization of design as a potentially alienating action or as segregating in providing equal safety based upon use, is a factor of inappropriate functional deviations. By addressing the removal of the known social separators in places where separation is detrimental to positive interaction, life-safety design dilemmas can be resolved before implementation.

The transition of a process-driven industry, from conceptual work and generation to the manifestation of artefact is through an understanding of form in relationship to a spectrum of human factors. This study explores this by examination of the environment's conditions through dynamic computer simulation. The exploration of computational data as a means of searching for opportunities in design which are both hidden and apparent, bridges affordability and accessibility within aesthetic and design sensibility. The opportunity to provide development criteria for creating a continuous physical connection to place reinforces universal accessibility, and satisfies an adaptive culture of diversification. The architect holds a "primary obligation and responsibility" to operate in the creation of the components of the built environment, and to safeguard health, safety, and welfare as defined by each state's general obligations of practice.<sup>7</sup> It is also becoming of architects to concern themselves with the creation of physical environments that maintain beauty and order while serving the spectrum of elements related to human function.

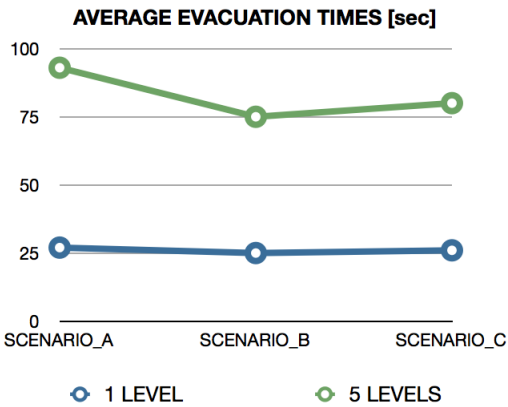
#### PARAMETERS

- 10 occupant-proxies exit into the fire stair per floor
- 1 disabled-proxy waits at the rescue area on every floor
- 1 fireman-proxy enters at the base of the stairwell / floor

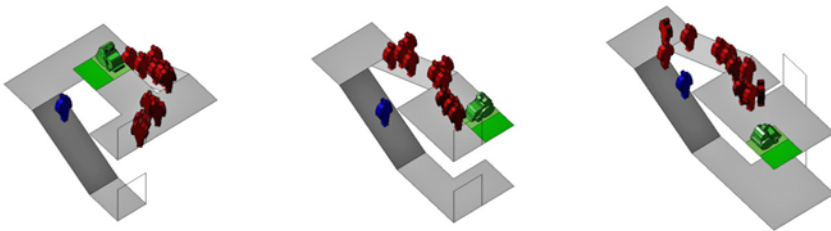
#### ASSUMPTIONS

- Proxies enter the stairwell 0.8s after the previous proxy
- Occupant-proxies travel down the stair at 45 in/sec (plus or minus up to 30%)
- Fireman –proxies travel up the stair at 35 in/sec (plus or minus up to 10%)
- Faster fireman-proxies will tend to rescue the disabled-proxies on the highest floors
- Proxies will avoid colliding with other proxies. When two proxies travelling opposite directions must pass each other, they will tend to move to their respective rights, if possible. Proxies try to avoid areas of extreme congestion, and will occasionally move wildly to extricate themselves if pressed.

These relationships are continuously in flux between analyzing the architectural artifact and architecture as the entirety of the built environment based on communities and regions. Experimentation with "off the shelf" products in the study of digital and computational based technologies, and in the generation of forms and multi-axis fabrication techniques, will help to evaluate conflicts with future versions of generative manufacturing techniques. Currently, the building industry process of suppliers distributing field-assemble components is inexpensive enough to compete with in-house fabrication. As the industry of in-house fabrication grows, I believe this will move from on-site assembly to on-site multi-axis fabrication and material based generative manufacturing techniques.



**Table 2:** Performative evaluation of egress patterns related to search and rescue one flight of stairs  
 \*\*(*Independent Study by university of Michigan students Parke MacDowell, Diana Tomova*)



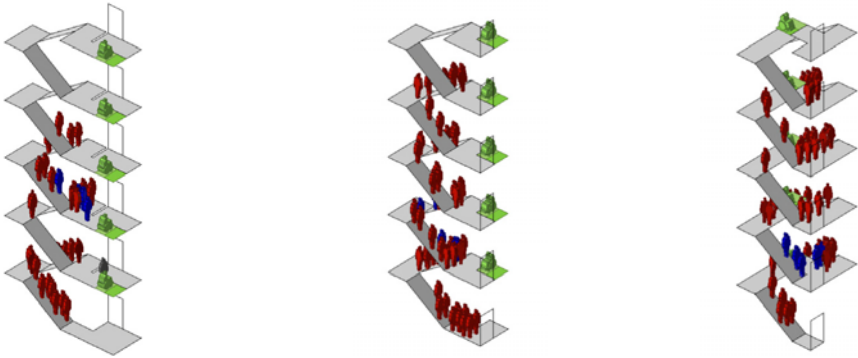
**Figure 1:** Performative evaluation of egress patterns related to search and rescue (one flight of stairs)

Mostly, the innovation in conceptual building processes will be associated with advancements in techniques for resolving design issues around the variables of human function needs.

Humanistic interface with object and spatial void is relevant to perception and the engagement of the user.<sup>8</sup> The possibilities for calculated computational modelling to resolve the issues of difference in human stature and access is a proving ground, evidencing that design can have a positive impact on human health. The use of techniques inherent in ergonomics as form generating parameters to inform the computational generation of architectural armatures is similar to the general practices of industrial designers who, in developing body styling that is responsive to environmental factors related to drag or other inhibitors, study how to resolve these technical issues through design. It is possible to understand the applicability of this technique to the field of architecture.

## 1.2. SPECIFIC APPLICATION OF COMPLIMENTARY EXPERTISE

Barriers affecting mobility impede connectivity beyond the physical restrictions of personal human impairment. The observation and documentation of human patterns of use to influence the forms that shape environmental mobility has been a key tool in understanding the social independence of a population.<sup>9</sup> Deliveries, strollers, and bicycles are all presented with similar difficulties in transiting across level changes as persons with limited physical abilities. Issues related to means of egress directly impact the health and safety of those in this category with limited physical abilities, exemplifying the need for level or limited slope exiting in emergency situations to prevent injury and loss of life in low-rise buildings. Human factor simulations based on variations in physical ability to study the range of possible users in scenarios associated with multi-story buildings (Figure 2), and can help a designer prepare alternative solutions in preventing injuries along a path of travel.



**Figure 2:** Performative evaluation of egress patterns related to search and rescue five flight of stairs

The selection of appropriate levels of information based on what our brains and bodies are capable of comprehending in emergency situations is another opportunity of study. The simulation of variables a user would experience based on immersion in a world of sensations, while populated with egress decisions. Many of the experiences tend to be directed towards singular sensory experiences, with very few balancing multiple sensory perceptions.<sup>11</sup> This changes in emergency situations, where the primary focus remains visual stimulation for orientation, often with disorienting audible warnings, and conditions that may affect orientation due to smell (taste) and touch.<sup>12</sup>

A sense can be defined as a general conscious awareness. By studying this awareness and understanding the corresponding behaviour, designers can define a set of variables for simulation through a variety of preceptors for understanding. The general premise would allow for a design to evolve from this perception; specifically, how the variables would simulate random human interaction based on the investigation of sense stimulation as a component of human factors simulation (Figure 3). The studies would produce a set of variables that could potentially enhance secondary orientation by senses in an equal manner as the physical one.<sup>13</sup>

The second half of the study is concurrently examining varying reactions and disorientations with light, sound, and touch. The simulation of patterns of behaviour in an active virtual model in association with the various qualities of materials and the resulting associated behaviour can give credence to placement and variations in form when rationalizing an architectural concept. The interpretation of the material as a variable based on the transitions between materials and their perception in various situations develops a virtual language of simulations of multi-axial and proximal relationships in simulating human awareness and orientation. The purpose of this is to inform the simulation of the barriers a user may encounter and randomly generate options in their orientation so that the designer can consider degrees of flexibility in the development of the form to affect its understanding.

By conjoining virtual spatial awareness with variations in sensory ability and considering the choice



**Figure 3:** Visual simulation of macular degeneration through videography

of preferred environmental responses, design dialogue becomes intended experience with the body and mind, which supersedes subjective awareness and aids resolution of conflicts over intent. The collection of these results is an inventory of understanding, advancing the database of perception and individual experiences in developing computational design criteria as related to varying physiological and psychological differences.

### 1.3. CONCLUSION

The physical and psychological capabilities of the human body change, and the flexibility of an environment to adapt to these changes through dynamic architectural forms could advance the shaping of the built environment. The capability of a design solution to adapt to the variation in physical capabilities by providing variations for equal use and cognition is an investment in the longevity of its use. This does not mean we wipe away the necessity of barriers that serve to provide security and control, but only that we find solutions that at least relate to the diversity and variation inherent in human physiology.<sup>14</sup>

Building Codes are only a part of the process of understanding the variables and decisions addressing the varying physical limitations of the built environment. By encouraging negotiable environments respondent to the pursuit of a greater quality of life for all, we might see ourselves as dynamic beings in constant transition, seeking to align our environment with our own changes, while the level of our capabilities diminishes around us. The strengthening the bonds between the critical thinking processes and the design thinking process itself fosters innovation, yet innovation without experience is detrimental to the goal. Collaboration between form generators and human factoring simulations addressing disability as primary language component for developing innovation in design can broaden the beauty of the solutions it produces.

#### ENDNOTES:

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